I-A 188 A Study of Mode Localization on Galloping Vibration in Two-Spanned Transmission Lines

Saitama University Student M N. Poovarodom
Saitama University Member H. Yamaguchi

1. Introduction

The periodic structures may exhibit a phenomenon known as mode localization. It has been found that the vibration modes are localized if there are irregularities in the periodicity of the system. The previous study [1] showed the causes and results of this phenomenon on a simple two degree-of-freedom system. In this study, the possibility of occurrence of this phenomenon in more realistic structure is investigated. The system consists of almost identical two span of 4-bundled cables, modeled for bundled transmission lines. The vibration of the system under galloping wind force will be discussed.

2. Model for Analysis

2.1 Structural Model

The 4-bundled cable with square spacer mounted on flexible support system is selected for this analysis, as shown in Fig.1. The static equilibrium under steady wind force and undamped natural frequencies and mode shapes are firstly obtained by the finite element method with a three node quadratic cable element. The angle of attack is calculated from the deformed configuration and the aerodynamic force can be computed. The complex eigenvalue analysis is finally performed in order to find natural frequencies and modal damping ratio of the system with aerodynamic damping. In the consideration of mode localization, the dynamic characteristics of the two-spanned cables are discussed by introducing a small (2.5%) perturbation in the length of one span.

2.2 Aerodynamic Force Model

The quasi-steady assumption is applied to evaluate aerodynamic force on the cross section shown in Fig.2. For first order approximation, [2]

$$F_y = 0.5\rho dU^2\left(-C_D(\dot{y}/U) + C_L(1-2\dot{z}/U)\right) \quad (1a)$$

$$F_z = 0.5\rho dU^2\left(C_D(1-2\dot{z}/U) + C_L(\dot{y}/U)\right) \quad (1b)$$

$$M = 0.5\rho dDU^2 C_M(1-2\dot{z}/U)\,, \quad (1c)$$

where ρ, U, d and D are air density, wind speed, cable diameter and bundle diameter, respectively. C_D, C_L and C_M are aerodynamic coefficients. Because the torsional motion of an individual cable is neglected, the effect of moment to the rotation of bundle is considered as a tangent force, F_M.

$$|F_{Mz}| = |F_{My}| = (M/4R)\cos(\pi/4) \quad (2)$$

The aerodynamic coefficients are assumed for one case of study as

$$C_D = 1.25 - 0.25\cos(8\alpha) \quad (3a)$$

$$C_L = 1.2\sin(\alpha) \quad (3b)$$

$$C_M = -0.2\cos(8\alpha) \quad (3c)$$

where $\alpha \approx \dot{y}/U$.

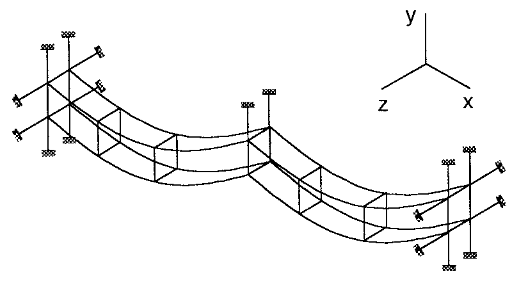

Fig. 1 : Bundled transmission lines model

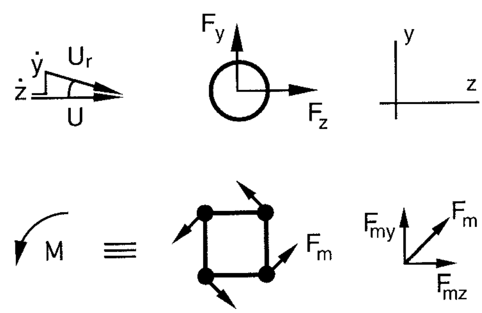

Fig. 2 : Aerodynamic force on cable

3. Undamped Eigenvalues Analysis

First of all, the natural frequencies and mode shapes of two-spanned cable system are obtained by undamped free vibration analysis. The details of results of eigenvalues analysis are given in reference [3].

The frequencies of the system are divided into groups or frequency bands. Each band consists of the number of closely spaced frequencies which is equal to the number of total subsystems; two in this case. The two modes are in-phase mode, in which the two spans have the same direction motions, and out of phase mode, in which the two spans have opposite direction motions.

In a particular mode, all cables in bundle have the same pattern of mode shape. The pattern of mode shape can be classified into three types dependent on the direction. In addition to in-plane and out of plane responses, the bundle cross section has rotational motion which is represented by the combination of vertical and horizontal displacements of each conductor.

4. Complex Eigenvalue Analysis

The cable system under a given wind speed is next analyzed for its damped natural frequencies and modal damping ratio. The results are shown for wind speed U = 2.0 and U = 10.0in Fig.3a and Fig.3b respectively. The left ordinate is for natural frequencies and the right ordinate is for modal damping ratio. The values shown as single mark are plotted against the abscissa of mode number. Note that the connecting lines are used to depict the graphs more clearly.

The results for the assumed aerodynamic coefficients in this study show that the natural frequencies, connecting with thin line, are almost identical for the order and disorder system due to assuming only small perturbation of span length. However, the results of modal damping ratio exhibit significant difference in some modes as can be seen when the thick dotted line shift away from the solid line. The cause of this difference can be explained by the understanding of mode localization. The strong localization can occur in the system with closely spaced frequencies. From the results of natural frequencies, the system has two frequencies in group, shown as two adjacent points. The closely spaced frequencies means that two adjacent frequencies locate almost at the same level. The corresponding modal damping ratio of the closely spaced modes resulted from mode localization can be observed to be remarkably distinct from the order system. The results from this model also show different degree of localization for different wind speed. The discrepancy of modal damping ratio is less significant in case of higher wind speed.

Because the modal damping is the parameter to estimate critical wind speed of galloping problem, the significant change of modal damping ratio due to mode localization phenomenon would affect the results of analysis.

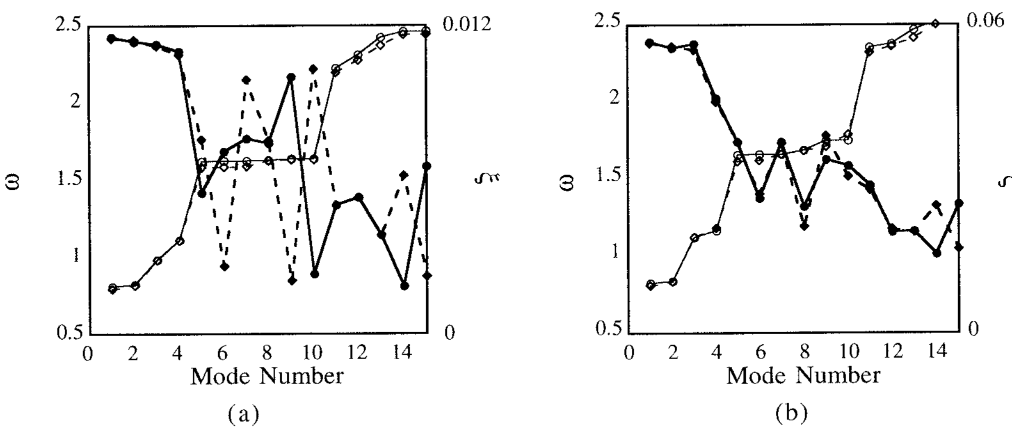

Fig. 3 : Natural frequency, ω, and modal damping ratio, ξ, a) U = 2.0, b) U = 10.0 ;
(—○—) ω order system, (- - ○ - -) ω disorder system,
(—●—) ξ order system, (- - ◆ - -) ξ disorder system

5. Concluding Remark

The study on mode localization in bundled two-spanned transmission lines under galloping force showed some effect on the modal damping values. The comprehensive study is required to proceed in order to understand the problem clearer.

References

1) Poovarodom, N and Yamaguchi, H. : Localization of vibration in nonlinear two-degree-of-freedom system, Journal of Structural Engineering, Vol. 42A, pp. 565-572, 1996

2) Jones, K. F. : Coupled vertical and horizontal galloping, Journal of Engineering Mechanics, Vol. 118, No. 1, pp. 92-107, January 1992.

3) Yamaguchi, H. and Poovarodom, N.: Mode localization in two-spanned cabled with flexible support, submitted for the XIXth ICTAM, Kyoto, Japan , 1996